ENERGY AND EVOLUTION

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The object of this paper is to develop the theory that species formation occurs during periods of increased activity, that plants which do the hardest (most difficult) work have evolved to the highest positions; that in this regard quality of products is more important than quantity; and that as morphological structures evolve from simple to complex, so plant chemical compounds evolve from simple to complex.

Species Definition from a Chemical Standpoint. - It is assumed that each species is in a state of mobile equilibrium between reversible reactions which fluctuate and are mutable under the action of modifying agents (Marcello, 1930). Individuality has, therefore, a complex chemical basis. The existence and permanency of a species is controlled and depends upon the existence of constant external and internal conditions and shows a fixed ability to synthesize characteristic compounds which constitute its physiologico-chemical characteristics (in part S. L. Ivanov, 1926). Thus, an increase in habitat temperature will stimulate the formation of more saturated fatty acids in glycerides and vice versa. Also, at moderately elevated temperatures starch is formed in evergreen leaves which is converted into oil when the temperature is gradually lowered and vice versa (Tuttle, 1919). As another instance of change of conditions affecting plant physiologico-chemical characteristics we know that an increase in water in the soil and in the plant promotes oil formation and vice versa (Sinnott 1917, Ivanov, Lavrova and Japochko 1931, Geddes 1934, Halden 1934). The concentration of electrolytes in plants is a factor controlling the amount of alkaloids and cyanogenetic compounds formed (McNair, 1941). As instances of the effect of internal conditions on plant chemical products we have the influence of changes in genetic constitution. Genetic strain affects HCN production in white clover (Williams, 1939) and sorghum (Nowosad and MacVicar, 1940). Genetic strain affects alkaloid production in tobacco (Rasmussen, 1915), opium (Annett and coworkers, 1920-1925),and aconite (Bonisteel, 1940, 1941), And genetic strain also affects the amount and distribution of oil in corn kernels (Pearl and Bartlett 1911, Lindstrom and Gerhardt 1926).

Species Developed During Greater Activity. - It is the consensus of opinion that although species may originate in a number of different ways they all originate during periods of greater activity. This greater activity may take place internally in or externally to the plant. According to geological evidence the splitting off of new species apparently falls within the times of greater range of variation in all characters, therefore of greater plasticity of species (Brinkmann, 1929). According to the biologists, especially physiologists, structure varies with function (Tait, 1928) and functional activity is emphasized as the foundation of structural differentiation (Leathes 1926, Fox 1932), or in the words of Pycraft (1930) changes of form are responses to continuous and persistent needs. The geneticists, as pointed out by Huxley (1941), have shown that new species may arise suddenly at a single bound. Instances of such greater activity are shown in chromosome-doubling (e. g. Oenothera), the inverting end-to-end, of a considerable section of one chromosome (e. g. Datura), or the detachment of a bit of one chromosome which may become attached to a different kind of chromosome (e. g. in Drosophila). A chemist, Henderson (1922), has suggested that apparent instances of orthogenesis may sometimes depend upon a single important chemical change in an organism, followed by slow and progressive modifications leading up to a definitive morphological result. Such a process, he says, might be somewhat analogous to the establishment of a condition of equilibrium.

Climate, Energy and Evolution. - As Parks (1926) points out from geological evidence, there is an undoubted tendency to increased complexity in the organic world. Consequently the greatest complexity in both form and substance may be expected to be found in such regions and in such plants as undergo the most rapid changes of external and internal conditions. There are, of course, optimum conditions above which the foregoing statement would not be true.

From a detailed study of the varietal diversity of cultivated plants and their wild relatives Vavilov (1932) found that the majority have had their origin in comparatively small territories concentrated mainly in the mountains and foothills of the subtropics and tropics. The mountain and foothill regions in the subtropics he found especially favorable for the development of species and varietal diversity. Mountains provide geographic types of isolation in the nature of differences between habitats - woodland and open country, pond and swamp, high ground and low ground, sunny southern slopes and shady northern slopes, canyons and ridges. These barriers isolate small populations and then useless accidental characters automatically accumulate. Much greater divergence is achieved on small areas (islands) as compared to large continental areas. Sewell Wright offers the explanation that if isolated populations are small enough in numbers, mere chance will step in and largely override the effects of selection.

Greater differences between habitats are found in the mountains of the tropics and subtropics than in those nearer the poles. We have in tropical mountains various life zones from tropical, lower sonoran, upper sonoran, transition, to boreal, while in mountains nearer to the poles some of these zones are absent.

In tropical lowland climates where conditions are more stable one would not expect to find the most highly evolved plants or the most complex chemical compounds. But rather the most highly evolved plants and the most complex chemical compounds would be found more likely in the subtropics and temperate zones where fluctuations of environment occur. For a similar reason aquatics with their more equable environment would be more primitive than land plants. In this connection Went (1941) has shown that in tomatoes either a high uniform temperature or a low uniform temperature did not promote nearly as much growth or fruiting as when a fluctuating temperature consisting of a high day temperature and low night temperature was provided.

Alkaloids. - If the alkaloids be first separated according to the habitat climates of the plant families producing them, it becomes apparent that the alkaloids of the highest molecular weight are produced by temperate plants and that those with the lowest are obtained from tropical families (Table I) (McNair, 1934).

The greatest number of plant families and also the greatest number of plant families from which alkaloids have been analyzed is found in the tropics. Some 299 alkaloids have been analyzed. All else being equal a largest number of analyses should lead to the most accurate results. Consequently tropical alkaloids are used. When this is done it is found that the higher the tropical plant family is in evolutionary development, the greater will be its tendency to form alkaloids of large average molecular weight (McNair, 1934).

Inasmuch as it generally requires more difficult work to produce chemical compounds of large molecular weight than those of small molecular weight, it can be argued that the higher evolved plants which likewise manufacture alkaloids of greater molecular weight perform more difficult work than more primitive plants.

A specific example in which the molecular weight of alkaloids may serve to indicate the degree of evolution of species is shown in the members of the genus Aconitum. Aconitum is noteworthy in giving a new chemical species of aconitine for each new botanical species analyzed, although all the aconitines are apparently closely related. Perhaps India is the center of distribution of this genus for here we find

A. chasmanthum Stapf with indiaconitine $C_{34}H_{47}O_{10}N$ (mol. wt. 629), A. demorrhizum Stapf with pseudoaconitine $C_{36}H_{49}O_{12}N$ (mol. wt. 687) and A. spicatum Stapf which contains bikhaconitine $C_{36}H_{50}O_{11}N$ (mol. wt. 672). Japan may be at the outer boundary of distribution with a more recently evolved species for here is found A. japonicum Thunb. which furnishes jesaconitine $C_{40}H_{51}O_{12}N$ (mol. wt. 737) of a higher molecular weight than the Indian alkaloids (Carr 1912, Schafer and La Cour 1934). In a comparison of the chromosome numbers with toxicity Bonisteel has found (1940, 1941) that the diploid aconites are for the most part non-toxic, while the triploid and tetraploid aconites contain some of the most powerful poisons known. There is, therefore, an increase in toxicity with an increase in chromosome number.

Glycerides. - Analyses of 318 fats (glycerides) are available for study. In Table I the fatty oils from temperate plant families have been separated from those produced by tropical plant families. It is apparent from this table that temperate fatty oils have higher average iodine values (and lower melting points) than the tropical (McNair, 1934).

As in the case of alkaloids, the greatest number of plant families from which glycerides have been analyzed is found in the tropics. By use of the more abundant tropical data it has been found (McNair, 1934) that the higher the plant family is in evolutionary development the greater will be its tendency to produce glycerides of large average iodine numbers (i. e. of greater unsaturation).

In the plant economy, saturated fatty acids are first produced which become less saturated later. In this way additional and more difficult work is necessary to form the less saturated fatty acids and consequently it is evident that the higher evolved plants which produce them perform harder, more difficult work.

The molecular weights of tropical glycerides (in agreement with the molecular weights of tropical alkaloids) are lower than those of temperate regions. Hilditch (1928) found that the tropical families Palmae and Myristicaceae had one specific fatty acid for each family, respectively lauric (mol. wt. 200, m.p. 48° C.) and myristic (mol. wt. 228, m.p. 58° C.) and that the temperate families Cruciferae and Umbelliferae had likewise one specific acid for each family, respectively erucic (mol. wt. 338, m.p. 33.5° C.) and petroselinic (mol. wt. 282, m.p. 14° C.). From this data it is evident that the average molecular weight of the tropical families, 214, is lower than that of the temperate, 310. As it requires more energy to compound fatty acids of higher molecular weight it is evident that these temperate families which likewise occupy a higher evolutionary rank have more difficult work to do than these tropical lower evolved families.

In the latest compilation of analyses of seed fats (Hilditch, 1940) data from sixteen natural orders (Engler and Prantl classification) are given. When the component acids of the families of these orders are considered it is found that seven orders have an increase in the number of acids, eight have an equal number of acids and one has a decrease in the number of acids with an advance in evolutionary position of their constituent families.

When the number of carbon atoms of these acids is considered it is found that eight orders have an increase in the number of C-atoms, six have equal numbers of C-atoms and two have a decrease in the number of C-atoms with an advance in evolutionary position. If, however, the terminal families of those analyzed of the Malvales, Myrtiflorae, Contortae and Tubiflorae (i. e. respectively Sterculiaceae, Myrtaceae, Asclepiadaceae and Acanthaceae) be removed from consideration, then three of these four orders show an increase in the number of acids and all four show an increase in the number of C-atoms in these acids with an increase in evolution. An increase in the number of C-atoms indicates in these instances an increase in molecular weight of the acids which contain them. It is hardly necessary to add that both an increase in the number of fatty acids as well as an increase in their molecular weights require an increased expenditure of energy.

Volatile Oils. - Nilov (1936) shows in a study of the essential oils in various stages of growth of Coriandrum sativum, Trachyspermum copticum and other plants that, parallel with the evolution of the plant, there occurs an increase in the complexity of the molecules.

In the volatile oils the genus Eucalyptus provides an excellent demonstration of the progressive increase in the number and variety of chemical products with the morphological advance in evolutionary position in the genus. These comprise in order of occurrence pinene, cineole, phellandrene, aromadendral (cuminal, cryptal, etc.) and piperitone (Baker and Smith data 1920). The amount of oil in the leaf also increases with the increase in evolutionary position, e. g. the most primitive average 1/2 of 1 per cent (e. g. E. corymbosa Sm.), while the most advanced (e. g. E. dives Schau.) have 2 per cent (4 times as much).

Volatile Oils, Specific Gravities. - Analytical data from 938 volatile oils is available for study. When the average specific gravities of the volatile oils produced by tropical and temperate plant families are inspected, it is evident that the volatile oils of tropical plant families have lower specific gravities than those produced by temperate plants (Table I) (McNair, 1932).

Further analysis of the more abundant tropical data shows that the higher the tropical family is in evolutionary development the greater will be its tendency to produce volatile oils of high specific gravity (McNair, 1934).

It can likewise be inferred (McNair, 1932) in accordance with these differences in specific gravity, that terpenes and compounds of the fatty (aliphatic) series predominate in the volatile oils produced lowest in the evolutionary position, while volatile oils formed by the families highest in evolution contain more aromatic, sulphur and nitrogen compounds. As more energy is generally required to produce aromatic than aliphatic compounds we can conclude that families highest in evolution carry on the most difficult work.

Volatile Oils, Refractive Index. - The refractive index is another property which may be used to measure variations in composition of volatile oils. From Table I it is evident that tropical volatile oils have higher values than temperate (McNair, 1932).

In addition it has been definitely shown (McNair, 1934) that the higher the tropical plant family is in evolutionary development, the smaller will be the average refractive index of its volatile oil.

It can likewise be inferred (McNair, 1932) that a small number or lesser amounts of saturated substances are formed in the volatile oils produced lowest in the evolutionary position. A high refractive index may also indicate a large quantity of compounds of high molecular weight; therefore it might be that the volatile oils produced lowest in the evolutionary scale have less of these compounds.

However, it has been observed in volatile oils (McNair, 1932) that a low index of refraction carries with it a concomitant increase in specific gravity. Consequently, a trend downward in the case of the refractive index (Fig. 5, McNair 1934) and upward in the case of specific gravity (Fig. 4, McNair 1934), indicate that the values verify each other in the case of evolutionary progression as well as in climatic difference.

It can therefore be concluded that the volatile oils of the tropical families highest in evolutionary development have constituents with a large number of double bonds (low saturation), more aromatic compounds, or more sulphur and nitrogen compounds with small amounts of substances of low molecular weight or small quantities of terpenes or bodies of the fatty series.

Because it requires more energy to form substances of high than of low molecular weight, aromatic than fatty (aliphatic) compounds, it can be concluded that plant families which manufacture these substances can be classed in the same manner. That is, that temperate volatile oil producing families are more energetic than tropical volatile oil families, and that in tropical volatile oil families those highest in evolutionary development are more energetic and perform more difficult work than those lower in evolutionary position.

Volatile Oils, Tropical Acids and Alcohols. - It has been shown from a consideration of both the specific gravity and refractive index of volatile oils that the higher the development of a tropical plant family the greater is the complexity of its chemical constituents. The study can likewise be continued to the various components of volatile oils, e. g. their acids and alcohols. When this was done, it was found that the heats of combustion of the alcohols and acids of tropical volatile oils increased in harmony with the increase in evolutionary differentiation of the plant families producing them (McNair, 1934).

The greater the heat combustion the greater the amount of energy required in the making of the burned compound. Consequently the higher the tropical plant family in evolutionary position the harder the work it has had to perform.

Plant Form Versus Energy and Evolution. - Aristotle long ago (384-322 B.C.) and his pupil Theophrastus (372-287 B.C.) classified plants as trees, shrubs and herbs, and this simple classification (in the words of A. M. Johnson) is the one we all first become aware of in our youth. It is plain that this classification is based on "life-form" and that the structure of the flower is ignored.

Eames (1911) brings forward evidence that the earliest dicotyledons possessed a solid tubular woody cylinder of considerable thickness which has gradually been reduced and finally broken up into a circle of separate strands, which is characteristic of the "typical" herbaceous condition. Such an hypothesis of reduction from primitive arborescent forms has also been worked out under the direction of Professor Jeffrey by several other members of his laboratory (Adkinson 1913, Bailey 1911, and Jeffrey 1912). In more recent papers, Sinnott and Bailey (1914, 1922) produced evidence in support of this view from paleobotany, phylogeny, anatomy and geographical distribution. It is no wonder that Bessey (1915) included in his "general principles adopted for the classification of plants" the postulate that "in certain groups, trees and shrubs are probably more primitive than herbs."

This hypothesis may be considered from the standpoint of the chemical products derived from plants. In Table II the glycerides, alkaloids and volatile oils from tropical plant families are considered in this respect.

From the final average obtained of the molecular weights of the alkaloids, there is a clear indication that trees produce alkaloids of lower molecular weights than shrubs, and that shrubs have lower alkaloid averages than herbs. Corresponding results are obtained from the iodine numbers of glycerides. The average refractive indices and specific gravities of volatile oils in respect to the dominant form of plant growth in the families is also developed in Table II. Here again the findings clearly indicate that trees may be the ancestors of herbs. This is shown in the specific gravities. It has been observed that volatile oils with a high specific gravity have a correspondingly low index of refraction (McNair, 1932). If then the specific gravities of volatile oils decrease from herbs to trees, the refractive indices should increase from herbs to trees. This is the case as shown by the averages (Table II). There is chemical support, therefore, for the contention of Bessey (1915), Sinnott and Bailey (1914) and others that in the angiosperms herbs have been derived from woody plants.

It has been shown previously in this paper that plants which manufacture glycerides of the highest iodine numbers, alkaloids with the largest molecular weights, volatile oils with the highest specific gravities and lowest refractive indices perform the most difficult work; therefore, it may be concluded that herbs which are higher evolved than shrubs or trees, also perform the most difficult work.

The chemical data used in Table II are condensed and rearranged according to plant form from McNair (1934). The following families used in the calculations are considered as consisting mainly of trees: Bombacaceae, Caricaceae, Dipterocarpaceae, Lecythidaceae, Moringaceae, Palmae, Rhizophoraceae and Winteranaceae; the families consisting mostly of shrubs and trees are Anacardiaceae, Anonaceae, Araliaceae, Bignoniaceae, Bixaceae, Burseraceae, Caryocaraceae, Cochlospermaceae, Combretaceae, Ebenaceae, Erythroxylaceae, Flacourtiaceae, Guttiferae, Hernandiaceae, Lauraceae, Meliaceae, Monimiaceae, Moraceae, Myristicaceae, Myrtaceae, Ochnaceae, Olacaceae, Oleaceae, Proteaceae, Salvadoraceae, Sapindaceae, Sapotaceae, Simarubaceae, Staphyleaceae, Symplocaceae, Tiliaceae, Vochysiaceae and Zygophyllaceae; mostly shrubs, Apocynaceae, Asclepiadaceae, Humiriaceae, Loranthaceae and Vitaceae; the families consisting mostly of herbs, shrubs and trees, Loganiaceae, Menispermaceae, Phytolaccaceae, Rubiaceae, Sterculiaceae and Verbenaceae.

Intensity of Assimilation. - Although the amounts of materials such as ligneous matter, sugars and chlorophyll assimilated in plant structures may not have a bearing on evolution, yet the rapidity of assimilation of some substances in plants apparently does have a bearing on evolution. For instance, by a rapid rate of metabolism in those plants which produce fruit only once in their lives, the foods and reserve materials necessary for fructification and seed production are produced in sufficient quantity more rapidly and earlier reproduction and death are thereby made possible. It is these plants of rapid metabolism which generally occupy the most highly evolved positions on the plant family tree.

Length of Plant Maturation Period. - In relation to the length of plant maturation period plants may be divided into two categories, those plants which bear fruit only once during their lives (monocarpic), and others which do so several times or frequently (polycarpic).

Plants which bear fruit only once generally tend to have the shortest longevity consistent with a normal reproductive period (Molisch, 1938). These germinate, develop and, as soon as they are fully grown, store reserve materials and then proceed to fructification, seed production and death.

This principle of the greatest possible abbreviation of a natural life does not apply to polycarpic plants, however, for we know that many such forms, particularly trees and shrubs, continue to live a long while, sometimes for many centuries after attaining maturity.

As monocarpic annual herbs have shorter plant maturation periods than polycarpic perennial shrubs and trees, and as annual herbs also occupy, in general, more recent evolutionary positions, therefore it can be concluded that these plants with shorter plant maturation periods work harder and are higher evolved than the longer maturing shrubs and trees.

PLANT PARTS. -- Length of Fruit Maturation Period. - The time consumed between the moment that the ovule becomes fertilized and the moment that the seed becomes viable varies greatly among plants. The length of this maturation period may require from a few weeks (*Tradescantia virginica*) to from two to three years as in the *Pinaceae* and *Myrtaceae* (Cheel, 1931). The shortest periods are found in monocarpic species and among the monocarpic species the ephemeral or annual plants generally require less time than the perennials. As the ephemeral or annual plants are herbs we have another instance where the greatest intensity of work is shown by plants highest in evolutionary position.

Flowers, Leaves and Stems. - The rate of metabolism appears to have a definite relation to the evolutionary position not only of the plant forms themselves (as shown above) but also of plant parts. Intensity of respiration can indeed be regarded, to a certain degree, as a measure of intensity of metabolism, since we know, for example, that flowers exhibit an unusually high rate of respiration, leaves less so and stems still less, and that the longevity of these organs parallels these rates, i. e., flowers live only a short period, leaves for a longer period and stems still longer.

The systematic position of a plant in evolution is determined mainly through flower differences. In the flower structure and function many more changes and more rapid changes have taken place than in either the leaves or stems.

The period of longevity of an angiosperm flower is here considered as extending from the first opening of the blossom to the final withering or shedding of its important parts (calyx, stamens).

So considered, the duration of flowers among various plants lasts from three hours to three months. If the plant puts forth only one flower (which is considered by some to be a more primitive condition than an inflorescence) annually, as is true of Galanthus, Moneses uniflora, Paris quadrifolia and the different species of Trillium, or when the flowers are only two or three in number, as in Cypripedium calceolus and the tropical orchids of the genera Oncidium, Stanhopea and Cattleya, these single flowers remain fresh and open a long time.

Evolution, we know, does not necessarily involve all parts of the flower at one time or in the same direction. One flower part may be advancing while another is stationary or retrograding. Because of this, all short-lived flowers are not all evolved to the same uniform degree of advancement, but nearly all of them are found on short-lived herbs (although staminate aments are on trees), and herbs constitute the most recent evolved plant form. Consequently it can be concluded that in general the flowers of shortest duration which also exhibit the most intense metabolism occupy the most advanced phylogenetic positions.

Leaves. - As compared with flowers, leaves are of greater duration; compared with the entire plant, however, they are rather short-lived, sometimes conspicuously so, except in those cases where their death is approximately simultaneous with that of the entire plant.

Under the most favorable circumstances the leaves of annuals attain the age of the plants which bear them, usually that of only one vegetative period, namely, several months.

The leaves of gymnosperms vary greatly from one hundred years (those of Welwitschia) to one year (Cupressus, Ephedra, etc.). The longevity of the leaves of the monocotyledons also varies from a number of years, as in the palms, to less than one year (Amaryllis, etc.). Although some of the leaves of the dicotyledons live as long as five years, many are in the one-year class.

There is, therefore, apparent decrease in the length of life (with an accompanying increase in intensity of work) of leaves as the plants on which they occur advance in evolutionary position.

Stems. - In general, it may be said, aside from exceptions, that the life of stems of herbs is relatively shorter than that of shrubs and trees as a whole. In the case of gymnosperms, woody stems and great longevity attain the ultimate dominace. And among monocotyledons long life prevails in the palms and shrubby forms, while short-lived annuals are relatively rare. In the dicotyledons short-lived annuals are more common.

It seems highly probable, therefore, that the position in evolution of some spermatophytes is indicated by the kinetic energy of their life cycles and the potential energy of some of their chemical compounds.

Summary

The object of this paper is to develop the theory that species formation occurs during periods of increased activity, that plants which do the hardest (most difficult) work have evolved to the highest positions; that in this regard quality of products is more important than quantity; and that as morphological structures evolve from simple to complex, so plant chemical compounds evolve from simple to complex.

Chemically each species is in a state of mobile equilibrium between reversible reactions.

The existence and permanency of a species depends upon the existence of constant external and internal conditions and shows a fixed ability to synthesize characteristic chemical compounds.

The splitting off of new species falls within the times of greater activity.

There is a tendency to increased complexity both in morphology and chemical compounds with evolutionary progress.

The stable conditions in the tropics are not as liable to produce these changes as the fluctuating conditions in the temperate zones.

Alkaloids are of greater molecular weight in temperate regions and likewise in the higher evolved tropical plants. Therefore higher evolved plants carry on more difficult work.

Glycerides produced in temperate zones and in the higher evolved tropical families have greater unsaturation (higher iodine values), and their fatty acids have higher molecular weights than the average tropical products. Thus more difficult work is performed by the higher evolved plants.

Volatile oils of temperate families and tropical families highest in evolutionary placement have constituents of low saturation, more aromatic compounds, or more sulphur and nitrogen compounds with small amounts of substances of low molecular weight or small quantities of terpenes or bodies of the aliphatic (fatty) series. Because it requires more energy to form substances of high than of low molecu-

lar weight, aromatic than aliphatic compounds, it can be concluded that plant families which manufacture these substances can be said to have reached an advanced place in evolution.

Volatile oil tropical acids and alcohols likewise show that the highest evolved tropical families form the acids and alcohols of greatest molecular weight and therefore promote more difficult work.

Trees are shown to do less difficult work than shrubs or herbs through a study of their alkaloid, glyceride and volatile oil production.

Plants that produce fruit only once in their lives (annual herbs) have a more rapid rate of metabolism than the polycarpic shrubs and trees. This rapid rate of metabolism is therefore indicative of more difficult work of the more highly evolved plant forms.

The length of the fruit maturation period is shorter in annual herbs than in shrubs and trees and therefore is an indication of the more difficult work carried on by the highly evolved herbs in apposition to that of the more primitive shrubs and trees.

Among plant parts longevity is a measure of metabolism. In this regard flowers greatly exceed leaves, and leaves exceed stems. The shortest lived flowers are produced by annual herbs and consequently exhibit the most intense metabolism, the most difficult work and occupy in general the most advanced phylogenetic positions.

It seems highly probably, therefore, that the position in evolution of some spermatophytes is indicated by the kinetic energy of their life cycles and the potential energy of some of their chemical compounds.

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Table I

Substances	Properties	Producing Climates	
		Tropical	Temperate
Glycerides	(iodine number)	85.36	124.00
Alkaloids	(molecular weight)	293.00	338.00
Volatile oils	(specific gravity)	0.9188	1.9232
Volatile oils	(refractive index)	1.4932	1.4879

Table II

Substances	Properties	Families consisting essentially of (average values)				
		trees	shrubs and trees	shrubs	herbs and shrubs	herbs
Glycerides	(iodine numbers)	66	94	96	102	117
Alkaloids	(molecular weight)	191	348	236	231	307
Volatile oils	(specific gravity)	.8878	.9175	.9010	.9340	.8875
Volatile oils	(refractive index)	1.4630	1.4938	1.4295	1.4918	1.4904

Table III

Comparison of Some Characteristics of Primitive and Higher Evolved Plants

	More Primitive Plants	Higher Evolved Plants
Environment	More stable environments e.g. tropics and water	More fluctuating environments e.g. temperate zone and land
Chemical components	Alkaloids Lower average molecular weights Glycerides Lower average melting points Lower average iodine numbers Lower average molecular weights Volatile Oils Lower average specific gravity More aliphatic compounds Higher average refractive index Fewer compounds of high molecular weight	Alkaloids Higher average molecular weights Glycerides Higher average melting points Higher average iodine numbers Higher average molecular weights Volatile Oils Higher average specific gravity Fewer aliphatic compounds Lower average refractive index More compounds of high molecular weight
Energy	Energy Less energy required to make compounds of lower molecular weight cited above Volatile oil alcohols and volatile oil acids with lower heat combustion	Energy More energy required to make compounds of higher molecular weight cited above Volatile oil alcohols and volatile oil acids with higher heat combustion

Table III - (continued)

	More Primitive Plants	Higher Evolved Plants
	Energy (continued) Therefore less energy required to make	Energy (continued) Therefore more energy required to make
Plant form	Trees more primitive Alkaloids Lower average molecular weights Glycerides Lower average melting points Lower average iodine numbers Lower average molecular weights Volatile Oils Fewer compounds of high molecular weight	Herbs more advanced Alkaloids Higher average molecular weights Glycerides Higher average melting points Higher average iodine numbers Higher average molecular weights Volatile Oils More compounds of high molecular weight
Intensity of assimilation	Intensity of assimilation Polycarpic plants have less	Intensity of assimilation Monocarpic plants have greater
Longevity of plant parts	Length of plant maturation period Polycarpic plants have greater Perennial shrubs & trees Length of fruit maturation period Polycarpic perennials (longer) Longevity of flowers Longer	Length of plant maturation period Monocarpic plants have less Annual herbs Length of fruit maturation period Monocarpic ephemeral or annual (shorter) Longevity of flowers Shorter

Table III - (continued)

More Primitive Plants	Higher Evolved Plants
Longevity of leaves Longer	Longevity of leaves Shorter
Longevity of stems Longer	Longevity of stems Shorter

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PLANT NOVELTIES

Harold N. Moldenke

ALOYSIA FONCKI (R. A. Phil.) Moldenke, Suppl. List Invalid Names 5, hyponym (1941), comb. nov.
Lippia Foncki R. A. Phil., Anal. Univ. Chile 90: 620. 1896

BAILLONIA AMABILIS var. PUBESCENS Moldenke, var. nov.
Haec varietas a forma typica speciei recedit ubique dense breviterque pubescentibus vel puberulis.

This variety differs from the typical form of the species in having its twigs, branchlets, petioles, and both leaf-surfaces densely short-pubescent, the racis and bracts densely puberulent or short-pubescent, and the calyx more or less puberulent.

The type of this variety was collected by my good friend and respected colleague, Dr. Frederico Carlos Hoehne [Com. Rondon 4739] at Triumpho, Rio S. Lourenço, Mattogrosso, Brazil, in February, 1911, and is deposited in the herbarium of the Departamento do Botânica do Estado, São Paulo.

CALENDULA OFFICINALIS f. PROLIFERATA Moldenke, f. nov.
Haec forma a forma typica speciei recedit ramulis 4--15 cm. longis in axillis bracteolorum involucri ornatis.

This form differs from the typical form of the species in bearing one or more short branchlets which issue from the axils of involucral bractlets beneath the main head of flow-